(54) Title: SYSTEM AND METHOD FOR DC OFFSET COMPENSATION IN A WCDMA RECEIVER
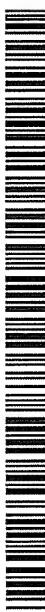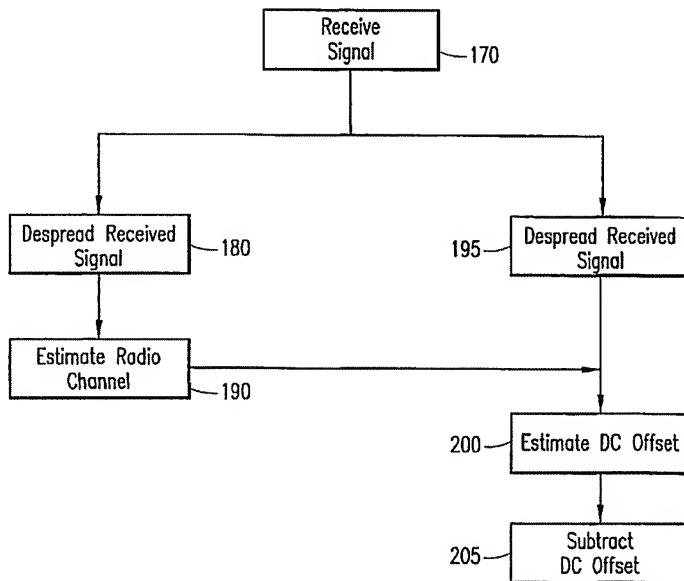
(57) Abstract: A system and method for DC offset compensation wherein a received first signal is despread using a first spreading code to generate a second signal. The second signal along with a first set of pilot symbols is used to estimate a radio channel. The first signal is also despread using a second spreading code to generate a third signal. A DC offset is estimated from the third signal, the estimated radio channel and a second set of pilot symbols. The estimated DC offset may then be subtracted from the second signal.

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SYSTEM AND METHOD FOR DC OFFSET
COMPENSATION IN A WCDMA RECEIVER

TECHNICAL FIELD

The present invention relates to RAKE receivers within CDMA systems, and more
5　particularly, to a system and method for compensating for DC offsets within a RAKE
receiver in a CDMA system.

BACKGROUND OF THE INVENTION

Today's high-performance wireless digital communication systems are based on a
10　radio access method called code division multiple access (CDMA). A particular extension to
CDMA is known as wideband CDMA (WCDMA) which is an access method standardized
within the 3G partnership project (3GPP). The WCDMA standard is the basis for 3G
cellular systems. WCDMA systems provide higher user data rates (bits/sec) than existing
CDMA systems. The current WCDMA standard offers up to 2 Mbps user data rate, and
15　even higher data rates are envisioned in the future. A new mode of operation referred to as
high speed downlink shared channel (HSDPA) is currently being standardized by 3GPP.
HSDPA offers user data rates of up to 10-15 Mbps per user. Such high data rates as those
utilized within WCDMA systems impose large demands on the digital receiver architecture
of base stations and mobile stations in terms of accuracy and speed. The additional
20　requirements for mobile equipment, as compared to receivers in stationary equipment,
include a need for low power consumption and low production cost. These requirements are
often contradictory to the new higher data rates.

One solution has been the use of direct conversion (homodyne) receivers. A direct
conversion (homodyne) receiver is a high-performance, cost-effective alternative to the
25　traditionally used superheterodyne receivers. However, the disadvantage with direct
conversion (homodyne) receivers is that they generate a DC offset. This offset must be
cancelled before data detection is commenced because the DC offset will severely degrade
the receiver's performance. Many different solutions have been proposed to suppress the
DC-components, and the majority of these methods use some kind of averaging to estimate
30　the DC offset within the signal.

A WCDMA system features, as one of the multitude of channels implemented within the system, a common pilot channel (CPICH) used for, for example, channel estimation. A WCDMA system implements a spreading factor (SF) for CPICH of 256 which suppresses the receiver-generated DC offset during the despreading process. The despreading process DC-suppressing ability is proportional to the spreading factor, and, hence, the DC offset is suppressed 24 dB (a factor of 256) when the CPICH is despread.

Each dedicated channel of the WCDMA system also features a number of pilot symbols (dedicated pilot symbols). A user data rate implies a rather low spreading factor on dedicated channels, (i.e., down to SF=4). The low spreading factor implies that the DC offset suppression due to despreading is relatively low, and the dedicated pilot-symbol estimates will contain a DC offset residue. Thus, there is a need for DC offset suppression techniques within high-speed WCDMA systems.

SUMMARY OF THE INVENTION

The present invention overcomes the foregoing and other problems with a RAKE receiver that includes a plurality of fingers enabling DC offset compensation. A first multiplier within each finger despreads a first signal to generate a second signal by multiplication with a first spreading code. A channel estimator estimates radio channels for the first signal from the second signal and a first set of pilot symbols. A second multiplier despreads the first signal to generate a third signal using a second spreading code. A summer estimates received data symbols including a DC offset from the third signal. A DC offset estimator estimates the DC offset for the received signal responsive to the estimated radio channels, the received data symbols including the DC offset, scrambling codes and orthogonal codes. A subtractor subtracts the estimated DC offset from the estimated received data symbols including the DC offset.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the method and apparatus of the present invention may be obtained by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings wherein:

FIGURE 1 illustrates a prior art WCDMA receiver;

FIGURE 2 illustrates a prior art finger of a RAKE receiver;

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FIGURE 3 illustrates the WCDMA receiver of the present invention;

FIGURE 4 illustrates a finger of a RAKE receiver according to the present invention;

FIGURE 5 illustrates an alternative embodiment for performing DC offset compensation within a RAKE receiver; and

FIGURE 6 is a flow diagram illustrating the operation of a RAKE receiver according to the present invention.

DETAILED DESCRIPTION

Referring now to the drawings, and more particularly to FIGURE 1, there is illustrated a conventional WCDMA receiver 10. A CDMA signal is received by means of an antenna 15. The received signal is down-converted, analog-to-digital converted, and sampled at a sample rate of M, which is typically 2-4 times the chip rate, to a baseband signal y_l within a front end receiver (Fe RX) 20. The baseband signal y_l is provided to a path searcher (PS) 25. The path searcher 25 determines and outputs the relative time delays $\tau_l ..., \tau_N$ (in samples) between the N dominant radio paths of the received signal. The relative time delays between the N dominant radio paths are used as inputs to a RAKE receiver 30. The signal y_l is an additional input to the RAKE receiver 30. The RAKE receiver 30 despreads the received signal y_l and estimates the radio channel for each radio path (or finger) within the signal y_l.

Referring now to FIGURE 2 there is illustrated one finger (radio path) of the N fingers within the Rake receiver 30. The signal y_l received from the front end receiver 20 is multiplied at 40 by scrambling code vector $d_{sc}(\tau_i, k)$ where τ_i is the i:th radio path delay from the path searcher, and k denotes which part of the total scrambling code that is used. The scrambling code vector $d_{sc}(\tau_i, k)$ comprises SF_l chips, and each chip is denoted $d_{sc}(\tau_i, k)$, $1 \leq l \leq SF_l$, since the scrambling code part is related to the symbol's position k in the data sequence. The multiplied signal is divided into two streams. The lower leg in FIGURE 3 is despread with the orthogonal code of the pilot channel, $d_{cp}(\tau_i)$ by multiplying it by the orthogonal code of the pilot channel at 45. The despread signal is used to calculate an estimate of the radio channel $\hat{h}_i$ for path i within the channel estimator 50. The signal in the upper leg in FIGURE 2 is despread with the orthogonal code for the data channel $d_{cd}(\tau_i)$, by

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multiplying it by the orthogonal code for the data channel at 55. The despread signal is summed and down-sampled to a symbol rate to provide estimated symbol samples. The symbol samples are denoted x^i_k, $1 \le k \le N$.

Referring back to FIGURE 1, the symbols from each fingers of the RAKE receiver
5 30 ($i = 1,...,N$) and the corresponding channel estimates $\hat{h}_i$ from the RAKE receiver 30 are fed to the Maximum Ratio Combining (MRC) unit 65. Maximum Ratio Combining (MRC) unit 65 combines the signals from each of the N fingers 35. The combined signal x_k is fed to the detection unit 70 in order to detect the transmitted symbol. The output from the detection unit 70 is the estimated symbol $\hat{u}_k$. This system, or course, does not use a direct
10 conversion receiver and does not require DC offset correction.

FIGURE 3 provides an illustration of a WCDMA receiver 75 according to the present invention. A signal is received via an antenna 80. The received signal is processed by a direct-conversion receiver 85 by down-conversion, analog-to-digital conversion, and sampling at a rate M, typically 2-4 times the chip rate, to generate a digital baseband signal
15 $y_l + m$. The signal $y_l + m$, where m is the DC offset generated in the direct-conversion receiver, is provided to a path searcher (PS) 90. The path searcher 90 provides an output of the relative time delays $\tau_1..., \tau_N$ between the N dominant radio paths, which is fed to a RAKE receiver along with the digitial baseband signal $y_l + m$. The RAKE receiver 95 despreads the signal and estimates the radio channel for each path.

20 Referring now to FIGURE 4, there is described a finger 98 of the new RAKE receiver 95, i.e., including the DC offset compensation. We assume a multi-path channel signal with N paths where h_j is the radio channel for path j, $d_{sc}(l - \tau_j, k)$ is the scrambling code, $d_{cp}(l - \tau_j)$ is the orthogonal code for the pilot channel, and $d_{cd}(l - \tau_j)$ is the orthogonal code for the dedicated data channel for delay τ_j. All codes are delayed τ_j chip according to
25 the information from the path searcher 90. Hence, the signal γ_l fed to the RAKE receiver 95 may be expressed as a sum

$$\gamma_l = \sum_{j=0}^{P} \gamma_j + m + e_l$$

$$= \alpha \sum_{j=0}^{P} h_j d_{sc}(l - \tau_j) d_{cd}(l - \tau_j) u(l - \tau_j, k) \qquad (1)$$

$$+ \sum_{j=0}^{P} h_j d_{sc}(l - \tau_j) d_{cp}(l - \tau_j) u^p(l - \tau_j, k) + m + e_l.$$

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Where α is a scale factor. Further, $u(k)$ is the transmitted data symbol, $u^p(k)$ is the transmitted common pilot symbol, m is the unknown DC offset, and e_l is noise on chip level.

The signal is split into two legs and despread with (d_{sc}, d_{cp}) and (d_{sc}, d_{cd}) at multipliers 110 and 105 respectively, and down-sampled to symbol rate. The cross-correlation resulting from the multi-path is included in the noise, i.e., the estimated common pilot symbols in the i:th channel can be expressed

$$z_k^{i,p} = h_i u_k^p + \frac{1}{SF_1} \sum_{l=1}^{SF_1} d_{sc}(l-\tau_i,k) d_{cp}(l-\tau_i) m + e_k^{i,p}, \qquad 1 \le k \le N_1 \qquad (2)$$

where N_1, is the number of common pilot symbols, and where $e_k^{i,p}$ is despread noise for the k:th common pilot symbol. The estimated dedicated pilot symbols can be expressed in a similar way

$$z_k^{i,dp} = \alpha h_i u_k^{dp} + \frac{1}{SF_2} \sum_{l=1}^{SF_2} d_{sc}(l-\tau_i,k) d_{cd}(l-\tau_i) m + e_k^{i,dp}, \qquad 1 \le k \le N_2, \qquad (3)$$

where N_2 is the number of dedicated pilot symbols, and where $e_k^{i,dp}$ is despread noise for the k:th dedicated pilot symbol. The received dedicated channel symbols will be used below but is shown here for completeness. In both of the above two expressions we have used that $|d_{sc}|^2 = |d_{cp}|^2 = 1$ and that d_{sc} and d_{cp} are orthogonal.

Typically, the number of pilot symbols used in the channel estimation process by the channel estimator 115 is about N_1, $= 10...15$. Considering that the spreading factor of the CPICH, SF_1, is large ($SF_1 = 256$ in WCDMA), and that $d_{sc},(\tau_i,k)$ is a PN-sequence, it is reasonable to assume that

$$\frac{1}{N_1} \sum_{k=1}^{N_1} \frac{1}{SF_1} \sum_{l=1}^{SF_1} d_{sc}(l-\tau_i,k) d_{cp}(l-\tau_i) m + e_k \approx 0 \qquad (4)$$

Hence, estimating the channel with correlation techniques, e.g.,

$$\hat{h}_i = \frac{1}{N_1} \sum_{k=1}^{N_1} u_k^p z_k^{i,p} \approx h_i. \qquad (5)$$

where $|u_k^p| = 1$, gives a good channel estimate.

The despread data signal z_k^i can, in the same fashion as above, be expressed as

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$$z_k^i = h_i u_k + \frac{1}{SF_2} \sum_{l=1}^{SF_2} d_{sc}(l - \tau_i, k) d_{cp}(l - \tau_i) m + e_k \qquad (6)$$

where we have used that $|d_{sc}|^2 = |d_{cp}|^2 = 1$ and that d_{sc} and d_{cp} are orthogonal. Since SF_2 is small (SF_2 can be as low as 4 in WCDMA), and since the number of dedicated pilot symbols typically can be $N_2 = 4$ per slot (see Figure 1), it is reasonable to assume that

$$\left| \frac{1}{N_2} \sum_{k=1}^{N_2} \frac{1}{SF_2} \sum_{l=1}^{SF_2} d_{sc}(l - \tau_i) m \right| > 0. \qquad (7)$$

Thus, the spreading gain of the dedicated pilot symbols is generally not sufficient to suppress the DC offset. Hence, the DC offset has to be estimated and removed before user data can be detected.

The estimation and removal of the DC offset is described below. The estimate of the radio channel, $\hat{h}_i$, the scrambling and orthogonal codes (d_{sc}, d_{sd}), and the a priori common pilot symbols $u_k^p, k = 1, ..., N_1$, are all fed to the DC estimation unit 125. In addition, the received despread dedicated pilot symbols $z_k^{i,dp}, k = 1, ..., N_2$, are also input to the DC estimator unit 125. The DC estimator unit 125 estimates the DC offset as

$$\hat{m}_i = \frac{\frac{1}{N_2} \sum_{k=1}^{N_2} (z_k^{i,dp} - \alpha \hat{h}_i u_k^{dp})}{\frac{1}{SF_2} \frac{1}{N_2} \sum_{k=1}^{N_2} \sum_{l=1}^{SF_2} d_{sc}(l - \tau_i, k) d_{cp}(l - \tau_i)} \approx m. \qquad (8)$$

The estimated DC $\hat{m}_i$ is then multiplied with

$$f_{k,i} = \frac{1}{SF_2} \sum_{l=1}^{SF_2} d_{sc}(l - \tau_i, k) d_{cp}(l - \tau_i). \qquad (9)$$

The resulting user data symbol x_k^i is now formed by subtracting $f_{k,i} \hat{m}_i$ at subtractor 130 from the received data symbol z_k^i. The corrected user data symbol x_k^i together with the

channel estimate $\hat{h}_i$ from each finger 98 of the RAKE receiver 95 are fed to the MRC 135. The MRC 135 combines the signals from each finger 98, and the combined signal is fed to the detection unit 140 to detect transmitted symbols.

Sometimes α is known, then the DC estimation procedure is the same as shown above. When α is not known, it has to be estimated. Thus, both α and m have to be estimated simultaneously. This can easily be done by extending eq. 8 to Least squares estimation, see below. Define

$$\alpha_k^1 = h_i u_k^{dp}$$

$$b_k^2 = \frac{1}{SF_2} \sum_{l=1}^{SF_2} d_{sc}(l-\tau_i,k)d_{cd}(l-\tau_i) \tag{10}$$

then

$$z_k^{i,dp} = \alpha a_k^1 + m b_k^2 + e_k^{i,dp} = A_k \theta + e_k^{i,dp} \tag{11}$$

and the LS estimate of $\theta = [\alpha \ m]^T$ is

$$\hat{\theta} = \left(\sum_{k=1}^{N_2} A_k A_k^T \right)^{-1} \sum_{k=1}^{N_2} A_k z_k^{i,dp} \tag{12}$$

Further, the alternative method can be extended including enhancement of the α estimate, i.e.,

$$\hat{\alpha} = \frac{1}{N} \sum_{k=1}^{N} \hat{\alpha}_i \tag{13}$$

Referring now to FIGURE 5, there is illustrated an alternative method for estimating the DC offset within the RAKE receiver 95. The DC offset m is common for all fingers, and the only difference between the fingers is the factor $f_{i,k}$. Hence, one possibility to obtain a better DC estimate is to make the DC offset compensation based on DC estimates from all N fingers 98. All fingers 98 will instead use the DC offset estimate where

$$\hat{m} = \frac{1}{N} \sum_{i=1}^{N} \hat{m}_i \tag{14}$$

where $\hat{m}_i$ is estimated according to

$$\hat{m}_i = \frac{\dfrac{1}{N_2}\sum_{k=1}^{N_2}(z_k^{i,dp} - \alpha\hat{h}_i u_k^{dp})}{\dfrac{1}{SF_2}\dfrac{1}{N_2}\sum_{k=1}^{N_2}\sum_{l=1}^{SF_2}d_{sc}(l-\tau_i,k)d_{cp}(l-\tau_i)} \approx m.$$

Referring now to FIGURE 6, there is illustrated a flow diagram describing the
method of operation of the RAKE receiver 95 of the present invention. The method for DC
offset compensation is initiated upon receipt of a signal at step 170. The signal is despread
at step 180 using a first spreading code to generate a first signal. Estimation of the radio
channel of the signal is made at step 190 using the first signal and a first set of pilot
symbols. The first signal is also despread at step 195 using a second spreading code to
provide a second signal. An estimation of the DC offset is made using the second signal,
the channel estimate, and a second set of pilot symbols at step 200. The DC offset
estimation made at step 200 is subtracted from the second signal at step 205.

The DC offset compensation described above is mainly required for high data rates
using low spreading factors. Thus, the receiver may additionally have the ability to turn off
the DC compensation block depending on which spreading factor is being used. The
described invention is particularly suitable for user equipment or base stations within
cellular communications stations. However, the system may be implemented within any
communication system requiring improved throughput in high data rate configuration.

The previous description is of a preferred embodiment for implementing the
invention, and the scope of the invention should not necessarily be limited by this
description. The scope of the present invention is instead defined by the following claims.

WHAT IS CLAIMED IS:

1.   A method for DC offset compensation, comprising the steps of:

receiving a first signal;

despreading the first signal using a first spreading code to generate a second signal;

estimating a radio channel of the first signal using the second signal and a first set of pilot symbols;

despreading the first signal using a second spreading code to generate a third signal;

estimating a DC offset using the third signal, the estimated radio channel and a second set of pilot symbols; and

subtracting the estimated DC offset from the second signal.

2.   The method of Claim 1, wherein the step of despreading the first signal using the first and the second spreading codes are performed at a plurality of different time offsets.

3.   The method of Claim 2, wherein the step of estimating the DC offset further comprises the steps of:

estimating a first DC offset at each of the plurality of different time offsets; and

estimating the estimated DC offset using each of the first DC offsets.

4.   The method of Claim 1, wherein the step of estimating the DC offset is contingent on the spreading factor for the second spreading code being lower than a predetermined threshold.

5.   The method of Claim 1, wherein the step of receiving further includes the step of multiplying the received signal by a scrambling code.

6.   A method of DC offset compensation, comprising the steps of:

receiving a first signal;

multiplying the first signal by a scrambling code vector to generate a second signal;

5   despreading the second signal using a first spreading code to generate a third signal;

estimating radio channels of the first signal using the third signal and a first set of pilot symbols;

despreading the second signal using a second spreading code to generate a 10   fourth signal;

estimating received data symbols including a DC offset from the fourth signal;

estimating a DC offset using the estimated radio channels, the estimated received data symbols including the DC offset, the scrambling code and orthogonal codes; 15   and

subtracting the estimated DC offset from the estimated received symbols.

7.   The method of Claim 6, wherein the step of estimating the DC offset further comprises the steps of:

20   estimating a first DC offset at each of the plurality of different time offsets; and

estimating the estimated DC offset using each of the first DC offsets.

8.   The method of Claim 1, wherein the step of estimating the DC offset is contingent on the spreading factor for the second spreading code being lower than a 25   predetermined threshold.

9.   A RAKE receiver, comprising:

a plurality of fingers, each finger comprising:

a first multiplier for despreading a first signal to generate a second signal using a first spreading code;

a channel estimator for estimating radio channels from the second signal and a first set of pilot symbols;

a second multiplier for despreading the first signal to generate a third signal using a second spreading code;

a summer for estimating received data symbols including a DC offset from the third signal;

a DC offset estimator for estimating the DC offset responsive to the estimated radio channels, the estimated received data symbols including the DC offset, scrambling codes and orthogonal codes; and

a subtractor for subtracting the estimated DC offset from the estimated received data symbols including the DC offset.

10.   The RAKE receiver of Claim 9, further including a third multiplier for multiplying the received signal by a scrambling code vector to generate the first signal.

11.   A WCDMA receiver, comprising:

an antenna for receiving a digital signal;

a direct conversion receiver for down-converting the digital signal to a baseband signal including a DC offset;

a path searcher for determining a delay between each radio path of the baseband signal including the DC offset;

a RAKE receiver for determining channel estimates for each radio path in the baseband signal including the DC offset and for determining DC offset compensated signals for each of the radio paths;

a maximum ratio combining unit for combining the DC offset compensated signals into a combined signal; and

a detection unit for detecting a transmitted symbol from the combined signal.

12.   The WCDMA receiver of Claim 11, wherein the RAKE receiver further comprises a plurality of fingers, each of the plurality of fingers comprising:

a first multiplier for despreading a first signal to generate a second signal;

a channel estimator for estimating radio channels from the second signal and a first set of pilot symbols;

a second multiplier for despreading the first signal to generate a third signal using a second spreading code;

a summer for estimating received data symbol including a DC offset from the third signal;

a DC offset estimator for estimating the DC offset responsive to the estimated radio channels, the received data symbols including the DC offset, scrambling codes and orthogonal codes; and

a subtractor for subtracting the estimated DC offset from the estimated received data symbols including the DC offset.

13.   The WCDMA receiver of Claim 11, wherein the RAKE receiver further comprises:

further including a third multiplier for multiplying the received signal by a

5   scrambling code vector to generate the first signal.

$$FIG.\ 1$$

Rake finger number i

$$FIG.\ 2$$

$$FIG.\ 3$$

Rake finger number i
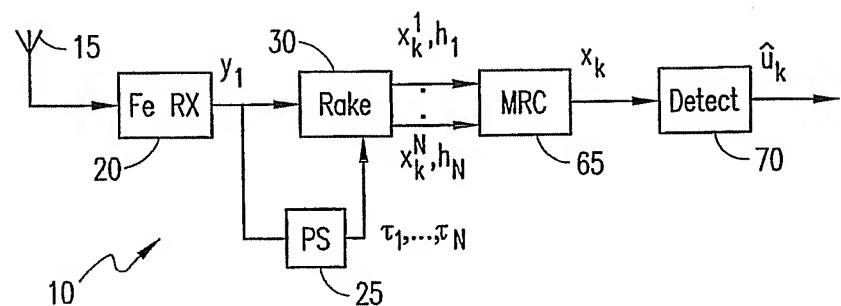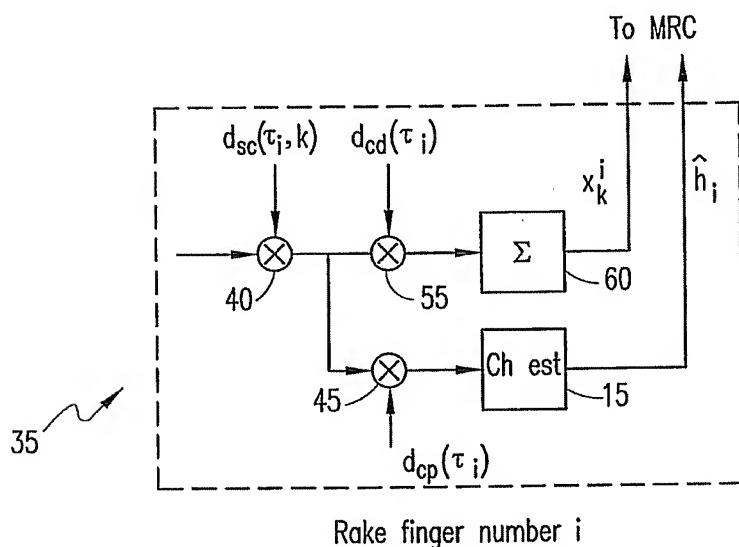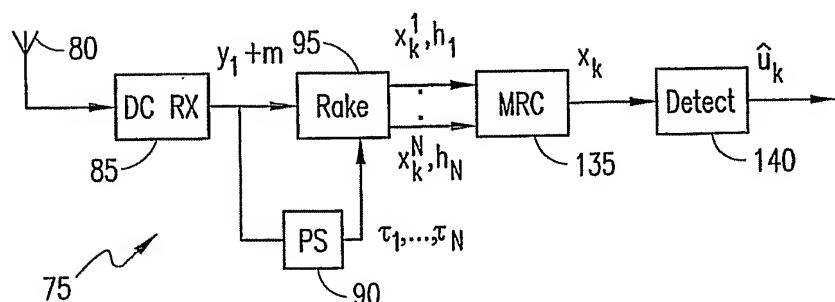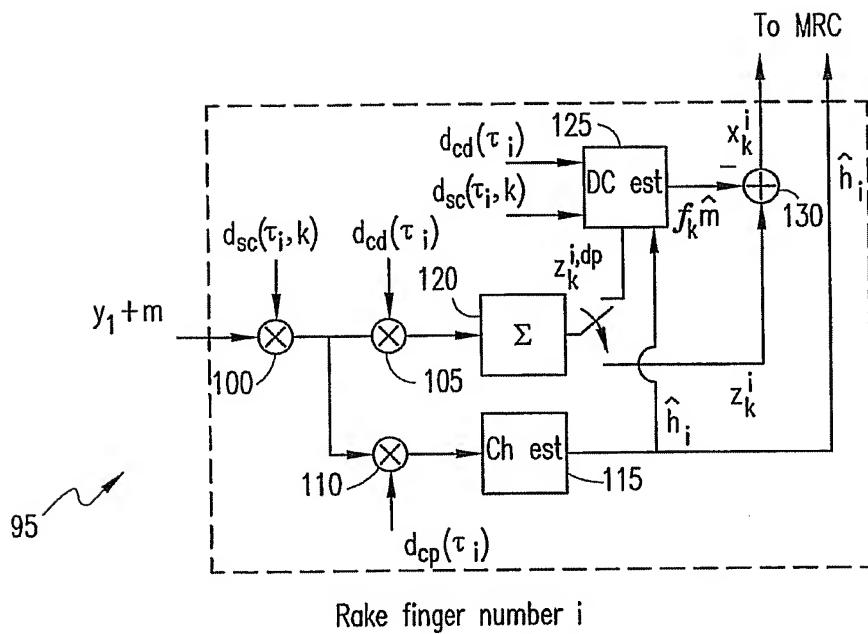
FIG. 4
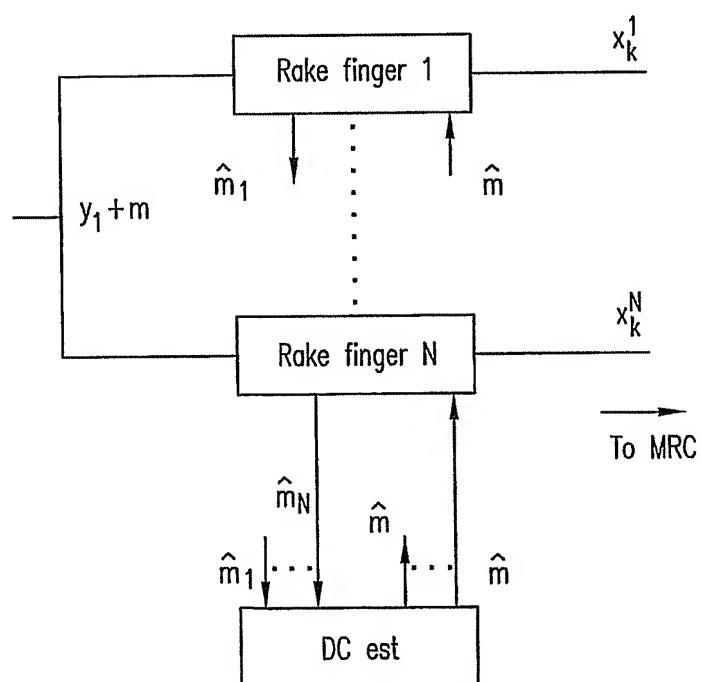
FIG. 5
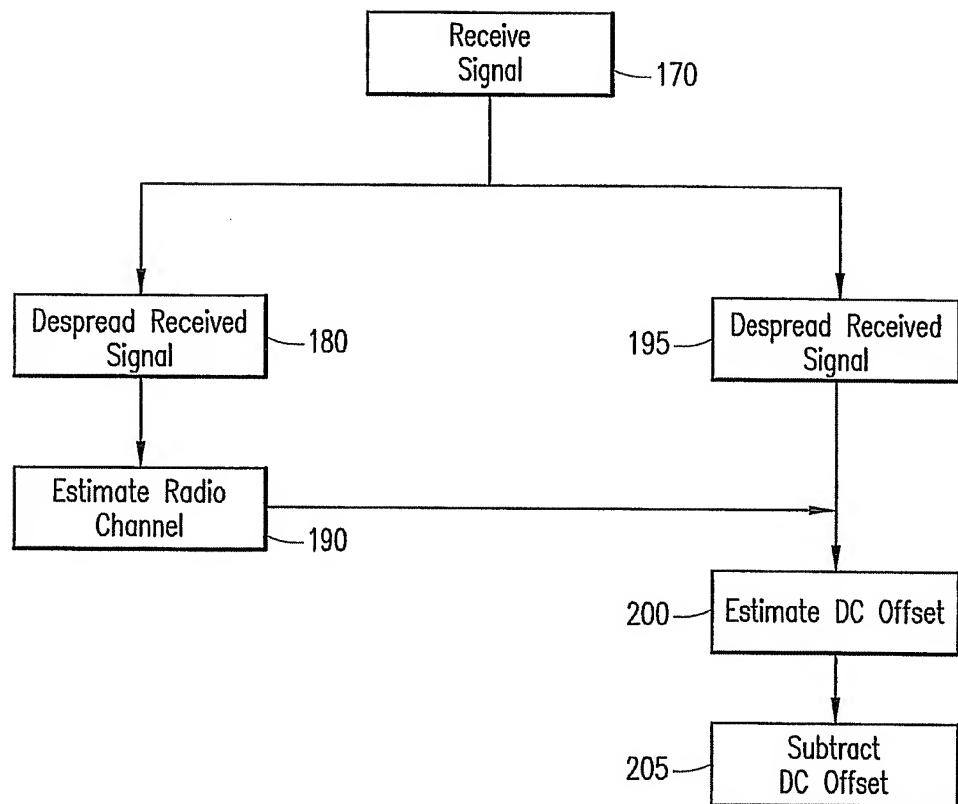
FIG. 6

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   H04B1/707   H04L25/06   H03D3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7   H04B   H04L   H03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 01 31867 A (NOKIA NETWORKS OY ;PIIRAINEN OLLI (FI)) 3 May 2001 (2001-05-03) abstract; claims 1,2; figure 3 page 12, line 11 -page 13, line 4 page 13, line 16 - line 24	1,6,9, 11,12
A	LINDOFF BENGT: "Using a direct conversion receiver in EDGE terminals-a new DC offset compensation algorithm" IEEE INTERNATIONAL SYMPOSIUM ON PERSONAL, INDOOR AND MOBILE RADIO COMMUNICATIONS, XX, XX, 18 September 2000 (2000-09-18), pages 959-963, XP002198497 page 960, paragraph III	1,6,9, 11,12

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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
24 March 2003	31/03/2003

| Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016 | Authorized officer Amadei, D |

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PARK C-H ET AL: "COMPENSATION TECHNIQUES FOR IMBALANCE AND DC-OFFSET LOSSES IN BLUETOOTH RECEIVERS" IEICE TRANSACTIONS ON COMMUNICATIONS, INSTITUTE OF ELECTRONICS INFORMATION AND COMM. ENG. TOKYO, JP, vol. E84-B, no. 3, March 2001 (2001-03), pages 682-687, XP001065632 ISSN: 0916-8516 page 685, paragraph 5.2; figure 7	1,6,9, 11,12

INTERNATIONAL SEARCH REPORT
Information on patent family members

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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			AU	1158300 A	08-05-2001
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